Evaluation of vegetal cover loss and its impact on surface temperature in Manipur valley using remote sensing and GIS technology, India

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Abstract: ***This study assesses forest cover change (1989–2016) in the Manipur valley using Landsat imageries and examines the quantum change in land surface temperature within the study area. Vegetation abundance is one of the most influential factors in controlling Land surface temperature. Vegetation change, NDVI and LST maps of four different dates are generated using Landsat TM images for 1989, 2002, 2009 and Landsat 8 OLI for 2016. Limited ground truth verification and field visits were conducted. The study reveals that the forests area decreased at an average annual rate of 330 ha year-1, amounting to a rate of loss of 8.6 % year-1 whereas the built-up area increases by 4 fold and the surface temperature simultaneously increases spatially over the study periods. The initial findings have shown that there is significant increase in the built-up areas, the conversion of forest cover into residential and commercial areas resulted in higher LST in impervious areas. Dense forest and water bodies comparatively observe low temperature than the built-up land. The study evaluates the relationship between the land surface temperature and vegetation cover loss, using Normalized vegetation index (NDVI) to indicate vegetation abundance. A strong negative correlation results between LST and NDVI, where the cooling effect of green areas can be observe. The results indicate a greater loss of the natural ecosystem to infrastructural development at the expense of forest class.***

Keywords: Land Surface Temperature (LST), Normalized Vegetation Index (NDVI), vegetation loss, climate change.

1. Introduction

Submit Land Surface Temperature (LST) has been used to assess the Urban Heat Island (UHI) and is a key parameter in controlling the water and energy balance between the atmosphere and land surface [10]. Urbanization transforms the natural landscape to modern land use and land cover such as buildings, roads and other impervious surfaces, making urban landscapes fragmented and complex and affecting the inhabitability of cities [2]. The rapid urbanization process brought about many eco-environmental problems, such as the drastic change of land use and development of urban heat island [14]. Urban growth on one hand contributes to economic welfare [15] and at the same time poses threats to environmental quality, including biodiversity [17], soil fertility [9], water quality [16,18], and effects on other natural resources [13] and ecosystem services [1,5].

The mass scale deforestation, the increasing built-up land, the use of materials like concrete, asphalt, tar, etc. have significantly altered the temperature than its surroundings; hence it can be used to detect land surface changes, e.g. tendencies towards desertification [3]. Rapid urban growth decreased the vegetated areas resulting rise in surface temperature and modified the urban microclimate [6]. With only about 10 percent of the state's total area, the Manipur central valley provide habitation to about 60 percent of the total population of the state. As a result, the valley is a thickly populated area with a density of 727 persons per sq.km. as against 54 persons per sq.km. in the hills. A similar differentiation exists in respect of the degree of urbanization with the valley at seven times of that in the hilly portions. The rugged topography of the hills and consequent lack of agriculture opportunities have made Manipur valley as hub of the economic activity of the state and subjected to an ever increasing human pressure. Thus, with this background this study evaluates the vegetation cover loss and estimate the relationship between the land surface temperature and vegetation abundance in the study area.

2. Study Area

The extent of the study area is shown in Figure 1, which includes Manipur central valley with surrounding 10 km buffer extent. The valley which has more population than the hills and dependent heavily to the valley is characterized by a phenomenal change in impervious land in last few years. The population density of the valley areas is over twelve times the hilly areas with an increase in population density from 630 persons per sq. km. in 2001 to 727 persons per sq. km. in 2011 (Census of India, 2011). According to various reports of Forest Survey of India (FSI), the state forest area deceases i.e. from 17475 km2 in 1987 to 16990 km2 in 2013 (FSI, 2013). However, the valley constitutes 2.05 % of total state forest area. Rapid urban development activities and increasing population over the last few decades in the Manipur central valley are one of the reasons to select as the study area.

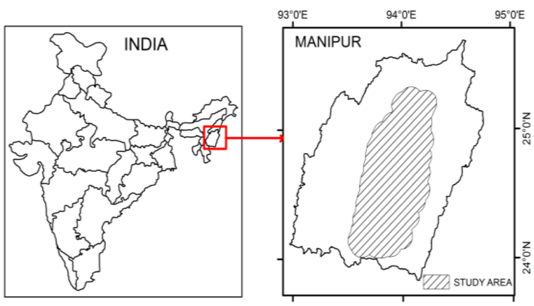

Figure. 1: Location of the study area

3. Title, Authors, Body Paragraphs, Sections Headings and References

The methodology adopted for this study is divided into four main stages; i.e. generation of vegetation map, NDVI assessment, land surface temperature (LST) retrieval and the estimation of the relationship between NDVI and LST. Cloud Free Landsat satellite data of 1989, 2002, 2009 and 2016 for the study area has been downloaded from USGS Earth Explorer website.

3.1 Generation of vegetation change maps

Landsat imageries are used to generate the vegetation maps of four different dates. The 27 year period is selected. The process of generating vegetation change maps is done using the ERDAS Imagine 9.1 software; a supervised classification method using maximum likelihood algorithm was adopted. The forest areas were classified into three classes with crown density greater than 40% included under dense forest, open forest with crown density 10-40% and degraded forest with crown density below 10%. Google Earth and data collected using GPS serve for ground thruthing. The accuracy of the images was checked with the overall accuracy of 76% in 1989, 73.9 % in 2002, 71.2% in 2009 and 80.7 in 2016, respectively, and Kappa accuracy of 74, 71, 77 and 78% for 1989, 2002, 2009, and 2016, respectively.

3.2 Derivation of NDVI Image

The Normalized Difference Vegetation Index (NDVI) is one of the most widely used index in monitoring the health of vegetation. The NDVI value of the pixels varies between -1 and +1. Higher values of NDVI indicate the richer and healthier vegetation. The index is defined by equation 1.

$$NDVI = \frac{NIR-IR}{NIR+IR} \quad (1)$$

3.3 Retrieval of LST

Satellite TIR sensors measure top of the atmosphere (TOA) radiances, from which brightness temperatures (also known as blackbody temperatures) can be derived using Plank's law (Dash et al., 2002). The following equation was used to convert the digital number (DN) of Landsat TM TIR band into spectral radiance (Lλ) using the equation supplied by the Landsat user's hand book [12]:

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\,max}}\right) Q_{cal} + LMIN_\lambda \quad (2)$$

where,
L_λ = spectral radiance at the sensor's aperture in W/(m2.sr.µm); Q_{cal} = Quantized calibrated pixel value in DNs; Q_{calmin}= minimum quantized calibrated pixel value (DN =)) corresponding to $LMIN_\lambda$; $LMIN_\lambda$= Spectral radiance that is scaled to Q_{calmin} in W/(m2.sr.µm); $LMAX_\lambda$= Spectral radiance that is scaled to Q_{calmax} in W/(m2.sr.µm).
The above equation can also be defined as
$L_\lambda = G_{rescale} \times Q_{cal} + B_{rescale}$

where,

$$G_{rescale} = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\,max}}\right)$$

$$B_{rescale} = LMIN_\lambda$$

I. **TABLE I.** L_{MAX} AND L_{MIN} VALUES OF LANDSAT DATA

Satellite/sensor	L_{max}	L_{min}
Landsat 5 TM	1.238	15.600
Landsat 8 OLI	22.00180	0.10033

The effective at-sensor brightness temperature (TB) also known as black body temperature is obtained from the spectral radiance using Plank's inverse function.

$$T_B = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (K) \qquad (3)$$

II. **TABLE II.** THE CALIBRATION CONSTANTS K1 AND K2 OBTAINED FROM LANDSAT DATA USER'S MANUAL

Sensor	K1	K2
Landsat 5 TM	607.76	1260.56
Landsat 8 OLI (band 10)	774.89	480.89
Landsat 8 OLI (band 11)	1321.08	1201.14

$$S_t = \frac{K_2}{1+\left(\lambda \times \frac{T_B}{\rho}\right) ln\varepsilon} \qquad (4)$$

Lλ = Radiance, S_t = Surface temperature, T_B= brightness temperature, ε= emissivity {0.004Pv + 0.986}

$$P_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2$$

$$NDVI = \frac{NIR - IR}{NIR + IR}$$

where, k = wavelength of emitted radiance (for which the peak response and the average of the limiting wavelengths (k = 11.5 Am) [4] will be used), q = h_c/j (1.438_10_ 2 m K), j = Boltzmann constant (1.38_10_ 23 J/K), h = Planck's constant (6.626_10_ 34 J s), and c = velocity of light (2.998_108 m/s). The NDVI image was computed from visible (0.63–0.69 Am) and near-infrared (0.76–0.90 Am) bands of the ETM+ image, so that the relationship between LST and NDVI can be studied.

4. Results and Discussions

The total forest cover in the study area has drastically decreased. The average rate of deforestation was 4462 ha year-1 amounting to a rate of loss of 5.3 % year-1. The increasing pressure on forest can be felt by decreasing percentage (74%) of dense forest category from 19.6 percent in 1989 to 5 % in 2015. Built-up land increases by 5 folds during the study period 1989-2016. The open forest and degraded forest also increases by 15 percent and 72 percent respectively.

III. **TABLE III.** VEGETATION COVER CHANGE INTO BUILT-UP AREA DURING 1989-2016 (AREA IN HECTARE)

LULC	1989-2002	2002-2016	1989-2016
Dense forest	95.4	340.68	526.5
Open forest	343.6	905.76	1594.9
Degraded forest	7994.1	9290	16131.6
Other landuse	9385.19	22910.3	34085

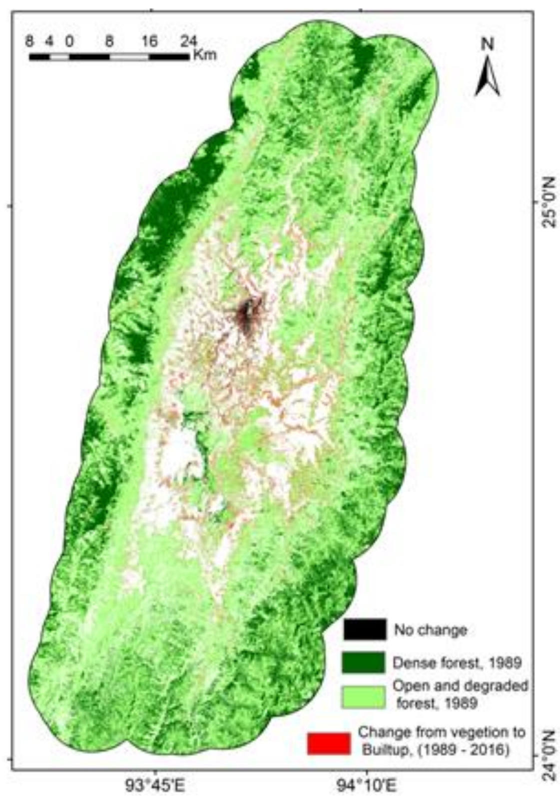

Figure. 2. Vegetation Change map from 1989 to 2016

4.1. NDVI Difference

Lower NDVI values are clearly evident water bodies and built-up areas. Fig. 3 show the NDVI maps generated from the Landsat TM for 1989, 2002, 2009 and Landsat 8 OLI for the year 2016. The NDVI value in the study area decreases from 0.77 in 1989 to 0.53 in 2016 which indicate greater loss of vegetation. Due to the increasing population pressure on the central valley, the area has been transformed to new built-up area causing vegetal degradation to supplement the need of population.

4.2. Land Surface Temperature

From brightness temperature (TB) and Emissivity images the final Land Surface Temperature image was obtained by developing a model in ERDAS Imagine 9.1. From the Fig.4 it is apparent that the built-up land other impervious areas in the valley have higher temperature comparatively than the surrounding vegetation and water bodies observed to be lower in land surface temperature.

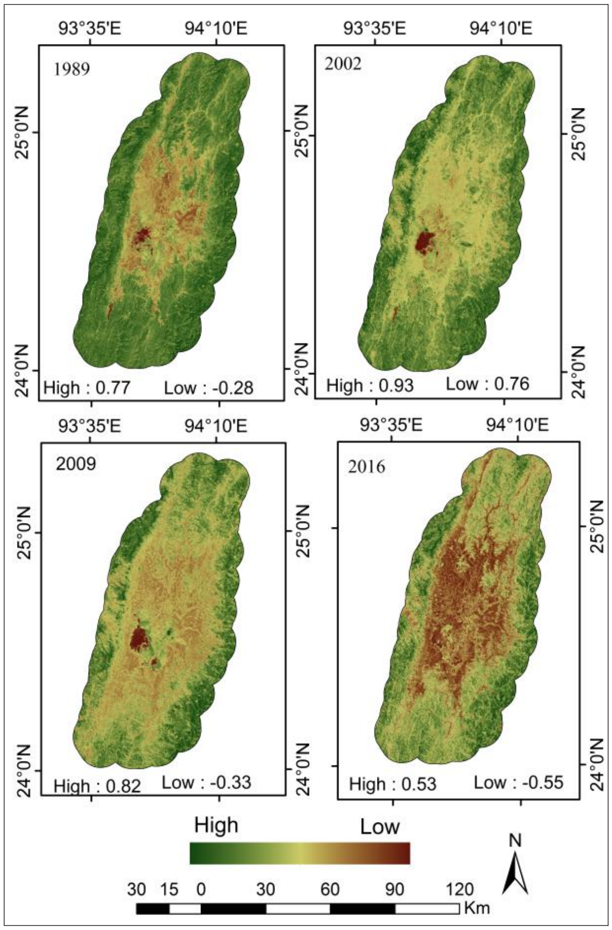

Figure. 3. NDVI maps of the study area

4.3. Land Surface Temperature

From brightness temperature (TB) and Emissivity images the final Land Surface Temperature image was obtained by developing a model in ERDAS Imagine 9.1. From the Fig.4 it is apparent that the built-up land other impervious areas in the valley have higher temperature comparatively than the surrounding vegetation and water bodies observed to be lower in land surface temperature.

4.4. Relationship between LST and NDVI

The correlation coefficient so obtained between LST and NDVI is found to be -0.74 and -0.61 indicating a strong negative correlation between LST and NDVI. A bivariate regression analysis is carried out to determine the correlation between these two parameters where the value of R2 decreases from 0.65 in 1989 to 0.27 in 2014 which shows the increasing variation among the NDVI and LST. Hence areas with least vegetation are experiencing more land surface temperatures. The population pressure and increasing built-up land is one of the causal factor responsible for increase in LST. Built-up of such excess heat as shown in fig.4 in the urban areas is due to the reductions of vegetation cover and increase in impervious land.

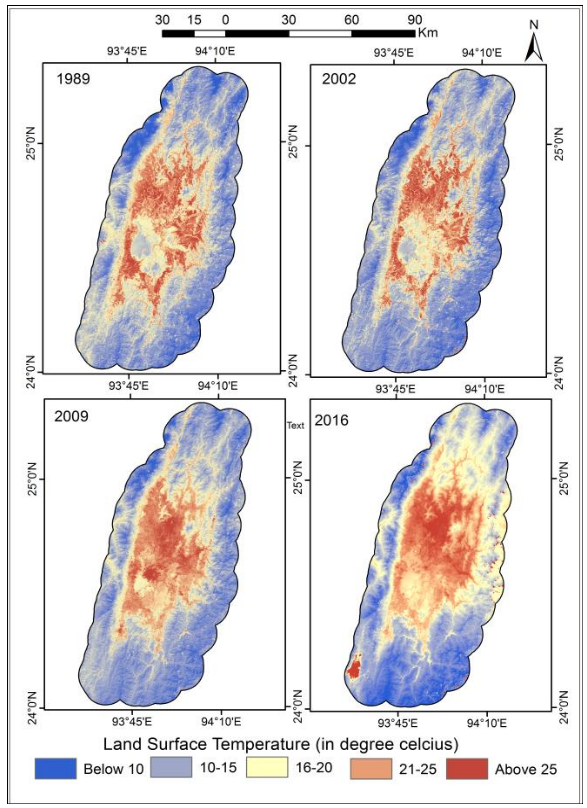

Figure. 4. Land Surface Temperature for 1989, 2002, 2009 & 2016

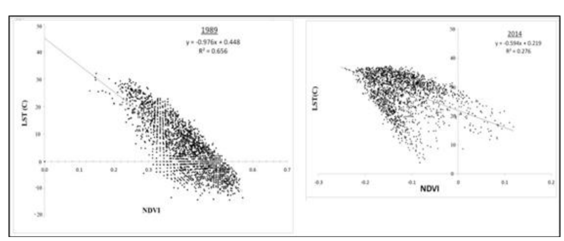

Figure. 5. Relationship between NDVI & LST of the study area for 1989 and 2016

5. Conclusion

The vegetated landscape underwent unwanted changes in the study area. Initial findings have shown that there is significant loss of vegetation in and around valley and an increase in the built-up areas over a period of 27 years which resulted in higher LST in the valley as compared to the neighboring hills or the vegetated areas. There is strong negative correlation between LST and NDVI, which indicates vegetation helps to reduce the LST of an area. The study reveals that appropriate strategies are necessary for the sustainable management of the urban area in the valley.

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